Recommended Practice of Library Lighting

Prepared by the Committee on Library Lighting
of the Illuminating Engineering Society

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Foreword

This first "Recommended Practice of Library Lighting" was developed by the I.E.S. Library Lighting Committee which was formed in July, 1946 following requests for a study of library lighting from the American Library Association and architects specializing in library design.

LIBRARY LIGHTING COMMITTEE
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1. Introduction

(a) This Practice considers lighting for both public and institutional libraries; recognition is given to (1) the possible wide range in the ages and educational levels of the library visitors, (2) the varying conditions of eyesight found within those groups, and (3) the varieties of reading materials that are currently used. Techniques are discussed for lighting high-ceiling areas, both decorated and plain, and also for some of the new modular designs which have relatively low ceilings.

(b) Many of the libraries now in use were designed with as much emphasis to the architectural features of the building as a public monument as to the utilization of the building for library purposes. The modern library is not merely a storehouse for books and periodicals; it is aggressively educational with facilities designed to make available a broad educational program to the public in all walks of life. Some of the new libraries have rooms for lectures, demonstrations, and seminars; facilities for projecting still or motion pictures; and sound-conditioned rooms where musical records can be played. Study rooms, carrels,** and research aids are provided as well as special rooms and display cases for showing rare books and historical collections.

(c) This report (1) recommends lighting practices employing modern sources and techniques for new libraries being designed and (2) suggests methods whereby present libraries now inadequately lighted can bring their lighting standards up to those needed if they are to fulfill the modern expanded educational function. The shortcomings of many present-day lighting installations include:

(1) Illumination levels below those needed for efficient and comfortable reading.

(2) The major dependence upon table lamps for reading purposes.

(3) Dark furniture and interior finishes which produce uncomfortable brightness differences with the reading task.

(4) Reading tables with glossy tops which create reflected glare, especially from table lamps.

(5) Glaring lighting units.

(6) Stack lighting with bare or inadequately shielded lamps. The lamps are glaring and the amount of illumination is inadequate between lamps and on the bottom shelves.

2. Analysis of Seeing Tasks

2.1—*Reading*

2.1.1—*General*—Reading is by far the visual task performed most often in a library. In the recommendation of environmental conditions and footcandles for optimum reading efficiency and comfort, three factors capable of very wide variation must be taken into account: (1) the condition of the reader's eyesight, (2) the character of the reading material, and (3) the reader's intensity and purpose. An additional factor is the angle between the page and the reader's line of vision. (See Appendix A for a discussion of reading racks.)

2.1.2—*Condition of Eyesight*—Public libraries serve people of all ages from elementary school children to grandparents. Statistics on the prevalence of defective vision indicate that the percentage of defective vision among children is low, but that it increases in percentage with added years. Statistically, 95 per cent of persons at the age of 70 have defective vision. The optical defects of many persons' eyes can be totally or partially corrected with glasses; some can be helped only. Although good lighting and seeing conditions are desirable for all readers whatever the condition of their eyes, they will be particularly helpful to older persons and others who have subnormal or uncorrected vision.

2.1.3—*Varieties of Reading Tasks*—In any library there will be found a great variety of reading tasks, some easy, others difficult. Typical of easy ones are children's books, and textbooks and novels printed in 10- to 14-point type, well-leaded, on good, white, non-glossy paper. By contrast are newspapers printed in 7-point type, unleaded, on low-contrast, off-white pulp paper; and law books which usually have long paragraphs printed in condensed type. The readability of printed matter depends upon the type size and its contrast with its background; plus factors such as type face, length of lines, spacing between lines, and margin widths. It has been found that two to three times the illumination is needed for pencil work as for average printed matter because of the difference in contrast. It is intended that the lighting levels and environmental conditions recommended be broad enough to compensate for the range and difficulty of the visual tasks enumerated above.

2.1.4—*Intensity and Purpose of Reading*—The third variable is the intensity with which reading is done, or the purpose for which the visitor goes to the library. Some merely browse or select materials for reading elsewhere; college libraries and those designed

*Approved by the Council of the Illuminating Engineering Society November, 1949.

**Carrel — a small enclosure or alcove in the stackroom designed as a place for individual study or reading.

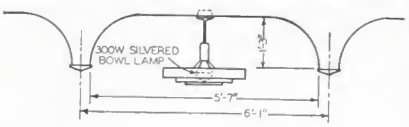

Figure 1. Reference Reading Room, Harvey S. Firestone Memorial Library, Princeton University: (a) (Above) daylight view; (b) (left) detail of coffers.

for professional research, however, are usually used for long periods of research or study. Intensive reading may occur in general reading rooms as well as in carrels or other rooms designed for study purposes. With the exception of children's rooms and areas set aside for browsing, the lighting level and environmental conditions for all reading areas should be selected with the expectation that some intensive study will be carried on there.

2.2—*Offices, etc.* — As a part of every library operation, there must be areas for regular office work and for other visual tasks such as indexing, cataloging, recording, typing and filing. For these, the same kind and amount of illumination employed in commercial offices will be suitable. Recommendations for most of these tasks will be found in the Illuminating Engineering Society's "Recommended Practice of Office Lighting," July, 1947.

2.3—*Book Stacks* — Several factors combine to make the lighting of stacks difficult, especially those to which the public has access. Although people are seldom in the stacks for long periods and their visual tasks are intermittent, they should be able to see all of the titles—top to bottom shelves—easily and quickly. Part of the difficulty in lighting book stacks is caused by the dark book bindings, by the small printing of the titles, and by the usually worn condition of the binding which partially obliterates the title. Another difficulty is caused by the long, narrow stack aisles, and the limitations as to the location of light sources in relation to the vertical surfaces to be lighted. On the other hand, the lighting of book storage and infrequently used stack areas which are used by library employees only can be much simpler; the footcandle requirements are lower, see Table III, and the need for low source brightnesses less urgent.

2.4—*Carrels* — Research and study carrels are reading areas often integrated with, or located close to the stacks.

3. Environmental Factors

3.1—*Brightness Ratios* — Although the eyes function most comfortably and efficiently when all brightnesses within the field of view are uniform, the attainment of such uniformity is not practical for many reasons. It is desirable and practical, however, to reduce extreme brightness differences within the normal field of view; see Table I. (The "central visual field" or seeing task is the book or periodical being read. The "immediately adjacent surface" is in most cases the table on which the book rests.)

TABLE I. — Recommendations for Limits of Brightness Ratios in Libraries

	Ratio
(a) Between the "central visual field," the seeing task, and immediately adjacent surfaces, such as between a book and the table top, with the book as the brighter surface.	1 to 1/3
(b) Between the "central visual field" (book) and the more remote darker surfaces in the "surrounding visual field," such as between book and floor.[1, 2]	1 to 1/10
(c) Between the "central visual field" (book) and the more remote brighter surfaces in the "surrounding visual field," such as between book and ceiling.[2]	1 to 10
(d) Between luminaires, or windows, and surfaces adjacent to them in the visual field.	20 to 1

[1]By using light floors (15 to 30% reflectance) ratios of 1 to 1/3 are possible.

[2]These ratios apply for areas of appreciable visual size as measured by the solid visual angle subtended at the eye, Luminous areas on luminaires are generally small in size in this respect. For the brightness limitations of luminaires, see Table V and (d) in Table I.

Figure 2. A public library illuminated by 500-watt indirect luminaires plus two 500-watt direct units through each skylight section. Resultant illumination is 30 to 40 footcandles. Note also the downlights over the attendant's desk at the right.

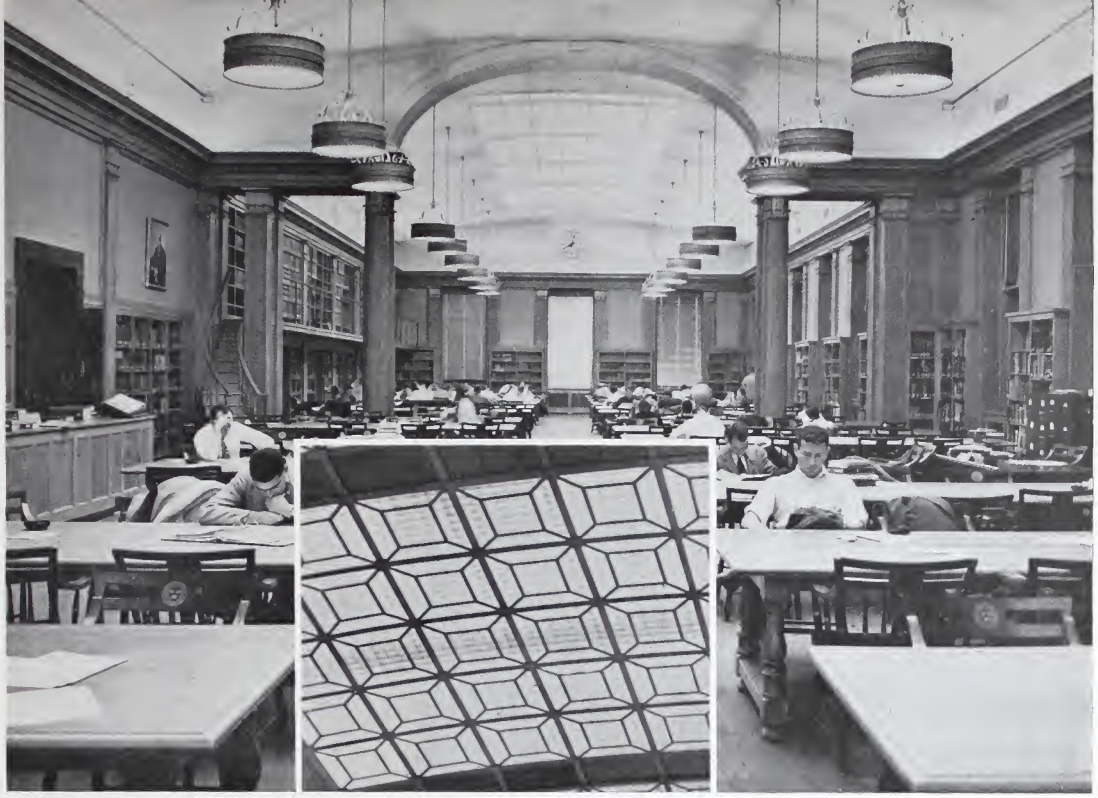

Figure 3. Three lighting techniques are combined to light the reading room of the Baker Library at Harvard University. Slimline lamps in metal reflectors are used over louvers in the former skylights (see insert photo); the large pendant luminaires (redesigned) each contain a 750-watt silver bowl lamp; a wood cornice above bookcases and ornamental paneling conceals cold cathode fluorescent covelighting. The result: 45 footcandles of diffuse illumination.

3.2—*Room Finishes*—(a) The ability to stay within the maximum brightness ratios of Table I will depend to a large degree upon the reflectance values of the room finishes; in conjunction with the lighting, they establish the brightness pattern of any room, and the brightness ratios between the task and other major surfaces within the normal field of view. White ceilings and light-colored walls help to reduce the brightness ratios between luminaires or windows, and surfaces adjacent to them. In addition to creating comfortable brightness ratios, the light colors recommended in Table II aid materially in the utilization of light.

TABLE II.—Recommended Reflectance Values (Per Cent)

Ceilings	80
Walls	50-55 ±5
Desk and Table Tops	30-35 ±5
Furniture	30-35 ±5
Floors	30-40 ±10

(b) In order to avoid annoying reflections, non-glossy surfaces are recommended for ceilings, walls, and table tops. Surface finishes are available for all of these which are acceptably non-glossy; they are easy to clean and collect dirt less rapidly than rough matte finishes.

3.3—*Reading Table and Desk Tops*—(a) In order to keep the brightness ratio between the reading table top and the printed page low, the reflectance of the table top must be higher than the dark-stained tables (10-12 per cent) commonly used. It is recommended that reading table and desk tops have as little specularity or gloss as possible. A highly polished table top will produce reflected images of bright unshaded windows, light sources, or bright ceilings; this reflected glare may be severe enough to offset any advantage gained by better environmental conditions or higher levels of illumination.

(b) Library furniture is now available in the new lighter finishes (24-28 per cent reflectance) as well as the dark, and materials and techniques have been developed for refinishing old furniture to give it the recommended surfaces. Table-grade linoleum is now available in blond-tan and mist-green colors that have 35 per cent reflectance; plastics that are rugged and simple to apply are available in sheet and fabric form; and oak table tops can be bleached and refinished with a non-glossy lacquer.

3.4—*Color*—The use of color in the library interior merits the consideration and advice of a color expert. The reflectance values recommended in Table II can be had in grays or in tints of warm or cool colors. From the standpoint of visual comfort and efficiency, it makes little difference whether the colors be warm, cool, or neutral. In the hands of an expert, however, color has many possibilities; rooms can be made to appear smaller by the use of warm tints, or larger by cool ones. Warm tints can be used in north and east rooms to enliven and warm otherwise drab interiors. Conversely, cool tints are often used in south and west rooms that seem to have an over-abundance of sunshine. In most libraries, color tints will be selected for their aesthetic values and usually by personal preferences.

Figure 4. High-ceilinged library at College of the City of New York. Old fixtures were raised about ten feet and lamp size reduced to eliminate glare, and sixteen 1000-watt downlights installed above ceiling.

TABLE III

	Footcandles Current Recommended Practice
DIFFICULT SEEING TASKS ..... Involving:	50
(a) Discrimination of fine detail (6-8-point type, footnotes, etc., legal reference books with small condensed type; illustrations with fine details, etc.).	
(b) Poor contrast (newspapers, maps; pencil notes, carbon copies, etc.).	
(c) Long periods of time (study; research reading). Illumination of this order is of benefit to those having subnormal eyesight; or for older persons carrying on work or reading of the following classification.	
ORDINARY SEEING TASKS ..... Involving:	30
(a) Discrimination of moderately fine detail (reading 8-12-point type, children's books; general and private office work; active file and mail rooms; cataloging; book repair and binding).	
(b) Better-than-average contrast (reading better magazines and books).	
(c) Intermittent periods of time (browsing; casual reading; book stacks open to the public; card files; check-in and check-out desks).	
CASUAL SEEING TASKS ..... Such as: Conference and reception rooms; stacks closed to the public; stairways and hallways used by the public; washrooms, checkrooms; and other service areas; auditoriums; book storage rooms where labels must be read.	10
SIMPLE SEEING TASKS ..... Such as: Corridors not used by the public; storage rooms involving no reading of labels.	5

The foregoing are recommended with no reference as to the type of illuminant, luminaire or type of lighting system.

4. Recommended Illumination Values

(a) The following footcandle recommendations are consistent with those in the "American Standard Practice for School Lighting," approved by the American Standards Association, September 20, 1948, and those in the "Recommended Practice of Office Lighting" published by the Illuminating Engineering Society in July, 1947. It is apparent that the visual tasks encountered in libraries are comparable in character to those in schools and offices and should, therefore, be consistent with them.

(b) The values listed in Table III are graded according to the difficulty of the visual tasks. These values should be maintained in service through proper cleaning and relamping of lighting equipment, the cleaning of windows, and the maintenance of the reflectance values of room surfaces. Initial values from the artificial lighting system must be greater by a percentage sufficient to compensate for the normal depreciation expected in service. (See Section 6.5)

5. Daylighting

5.1—*Advantages* — Windows serve two valuable purposes from the standpoint of the seeing tasks in the library: (1) they admit light into the interior which results in the desirable footcandles for seeing; (2) they permit the occupants to look out. The latter has an advantage in addition to the pleasure of looking to the out-of-doors; it permits the reader to focus his eyes for distant vision and thereby relaxes the eye muscles which are under tension from the close vision necessary for reading. It is important, however, that the benefits of daylight through windows be gained without offsetting them by seating arrangements such that large window areas of high brightness are in the field of view.

5.2—*Factors that Affect Natural Lighting* — The distribution and amount of daylight realized in an interior will depend upon many factors: the kind of glass; the number, size, shape and position of the window openings; the ratio of the window height to the room width; the kind of window shading; the amount of daylight outside; the presence of trees and buildings; the brightness pattern of the room; and possibly other conditions. See Appendix B for discussion of these factors. In addition, daylight itself varies greatly through each day and during the year. (See the I.E.S. "Recommended Practice of Daylighting," ILLUMINATING ENGINEERING, February, 1950.)

6. Artificial Lighting

6.1—*Lighting Systems*—(a) Artificial lighting systems are divided into the five following general classes based upon their distribution of light in the upper and lower hemispheres.

TABLE IV

Classification	Distribution of Light from Luminaires Upward	Downward
Indirect	90 -100%	10 - 0%
Semi-indirect	60 - 90%	40 - 10%
General diffusing	40 - 60%	60 - 40%
Semi-direct	10 - 40%	90 - 60%
Direct	0 - 10%	100 - 90%

(b) Systems of all types will have proper application in libraries although some care must be exercised in the selection of the system for reading rooms, offices, and similar areas where people are occupied with difficult visual tasks and are facing in one direction for long periods. The several characteristics presented in Appendix C should be considered also to make the lighting system consistent with the architectural characteristics of the interior.

6.2—*Light Sources*— (a) Judgment must be made also between the two types of light sources—filament and fluorescent lamps—currently used for interior lighting. Considerations of the two sources will include the suitability of the luminaire architecturally, the relative initial cost of the systems, and the cost of lighting per footcandle per year. (See Appendix D.)

(b) As to the suitability of the two illuminants for library purposes, researches indicate that, on an equal footcandle and quality basis, the two illuminants are equal in the visibility, comfort, and readability obtained. Both illuminants are now being used in libraries successfully.

6.3—*Brightness Limitations*— As a guide in luminaire selection for the range of footcandles given in the table of lighting levels (Table III), the brightnesses in Table V are recommended as maximum values both crosswise and lengthwise of the luminaire. Observance of these limits should avoid glare from luminaires under any normal circumstances of installation and room decoration. However, it is recognized that higher values than these have been used without detriment in installations where great care was taken to use light colors and matte finishes in the lower part of the room as well as the upper part, and where the bright areas of luminaires are small. It is recommended that where such conditions permit the use of luminaires of other than the indirect or semi-indirect types, approximately double the values given be accepted as the limits of brightness.

TABLE V

Zone	Recommended Brightness Limits in Footlamberts*
(0° is directly beneath luminaire)	
60° - 90°	225
45° - 60°	450
0° - 45°	1000

*Comparative values in candles per square inch respectively, .5, 1.0, 2.

6.4—*Flexibility*

6.4.1—*General*—It is very desirable to have enough flexibility in a lighting system to make it possible to convert from one footcandle level to another easily and quickly. Because of ever present changes in a library, it might be desirable to quickly convert a general reading room requiring 30 footcandles to a research study room which needs 50; this can be done in many cases without a major revision if properly planned. This requires that the wiring has adequate capacity for the maximum load that will be used. Following are some suggestions that may help to accomplish this desired flexibility.

6.4.2—*Filament Lamp Systems*—300 and 500-watt filament (incandescent) lamps are interchangeable in most luminaires, as are also 750 and 1000-watt. A 300-watt system producing 30 footcandles will produce 50 footcandles with 500-watt lamps. 1000-watt lamps generate 40 per cent more light than 750-watt lamps, making possible a change from 30 to 42 footcandles.

6.4.3—*Fluorescent Systems*— **(a)** Where fluorescent luminaires are spaced intermittently, with the proper space left between, additional equip-

Figure 5. Illustrating use of individual study lamps. Each study table has a lighting unit at the left end, but since tables are end-to-end against the wall they are well lighted from both sides.

Figure 6. Reading room and stack area, Lamont Library, Harvard University. Troffers for general lighting plus downlights over desks at left and fluorescent stack lighting units.

ment can be installed to make continuous rows.

(b) Where there are continuous rows of luminaires producing 30 footcandles, units can be added at right angles to produce a grid pattern. The luminaires selected should be free from glare when seen either lengthwise or crosswise.

(c) Systems using four-lamp equipment can be installed with pull-chain switches on one two-lamp circuit in each luminaire.

(d) Two-lamp troffers placed at right angles to the normal line of sight can be switched and wired so that continuous-row operation obtains whether one or two lamps are used.

(e) Certain types of fluorescent lamps may be operated at different current densities to obtain different light output values. This would require changes in ballasts.

(f) Ceilings of light with properly spaced and circuited lamps above the control media to produce the desired footcandle changes.

6.5—*Maintenance* — (a) Lighting equipment and room surfaces must be well maintained if reasonable efficiency and satisfactory appearance are to be realized. The elements which affect the overall efficiency of a lighting system are the light sources, the luminaires, and the room surfaces. Depreciation of 30 to 50 per cent may be expected depending upon decrease of lamp light-output, atmospheric dust conditions, and design of luminaire in relation to dirt collection.

(b) The output of all light sources diminishes with use, and in many cases it is economical to replace lamps before they finally fail. With planned lamp replacement schedules, savings may be realized by replacing groups of lamps near the end of their useful life rather than individual ones as they burn out. The depreciated lamps are replaced by those of peak performance. If lamps are replaced in alternate luminaires or in alternate rows of luminaires, more constant illumination is maintained.

(c) Lamps and lighting equipment collect dust and dirt which reduce lighting efficiency. The rate of depreciation is dependent upon the atmospheric conditions and the type of lighting system employed. A thorough washing of lighting equipment at least twice a year is economically justified in even the most favorable locations. Under adverse conditions, three or four cleanings per year are needed to achieve the lowest cost operation in terms of footcandle-hours per dollar. With proper cleaning schedules, an increase of at least 25 per cent is often realized in the average maintained value of illumination. Lighting units should be designed with minimum depreciation characteristics and easy maintenance features.

(d) The necessity for cleaning or painting room surfaces is also a function of the amount of dirt contained in the atmosphere. The rate of depreciation is materially reduced where air-conditioning and filter systems are employed, but it is very difficult to eliminate entirely dust and dirt in ordinary library areas. The distribution characteristics of the lighting system also influence the effect of room maintenance, since dirt on room surfaces is more detrimental to an indirect than to a direct lighting system.

(e) A regular program of window cleaning is also essential. Although the accumulation of dirt may not be as rapid in libraries as in factories, the windows require frequent washing to maintain them at reasonable effi-

Figure 7. Research library of a large company illuminated to 50 footcandles by troffers spaced alternately two and four feet apart.

ciency. Dirt on the inside and outside of windows frequently absorbs as much as 50 per cent of the light that might otherwise be admitted to the library area. At the same time, the diffusing effect of such dirt can result in high window brightness and direct glare.

(f) A realistic consideration of these various factors is essential to the efficient operation of the library lighting system. Even the cost of frequent maintenance is more than offset by the value of the additional illumination obtained.

7. Lighting for Specific Areas

7.1—*Reading Rooms*

7.1.1—*Table Lamps*—**(a)** In the past, table lamps, supplemented by low-level general lighting, have been accepted practice for illuminating libraries. Table lamps came into general use when the cost of general lighting was high; in those days, general lighting was commonly used for architectural decoration, for general space illumination, and as a supplement to local table lighting. However, lighting techniques as applied to many kinds of interiors have changed markedly in the past few years with the development of more efficient light sources and improved light controlling equipment. The trend in newer libraries is away from the use of table lamps and toward general lighting of a footcandle level and character suitable for reading purposes.

(b) The reason for this trend is evident when one considers the following shortcomings of conventional lamps:

(1) In order to get light from the lamp, the book must be laid flat.

(2) The reader must often accept the light from an awkward position depending upon where he is seated.

(3) Lamps falling in front of the reader create bad reflected images on glossy book or magazine pages.

(4) The best light is obtained only when close to a lamp. If lamps are widely spaced, some readers have less than enough light.

(5) The multiplicity of reading lamps in a large room creates a cluttered appearance and a continual maintenance problem.

Figure 9. Reading room at Case Institute of Technology, Cleveland, Ohio. Luminous indirect luminaires containing 500-watt filament lamps provide 30 footcandles on the table tops.

(c) For lighting individual study tables in research libraries and other rooms that have a low occupancy factor, individual reading lamps may be suitable as a supplement to a general illumination of medium intensity. It is good practice to have the reading lamps at the left side, or preferably, both sides of the table for the benefit of right or left-handed writers. Furthermore, the units should be so positioned that no reflected images occur in the glossy surfaces laid flat on the table. One such unit was used in officer-training study halls during the war. (See Fig. 5.) In this installation, each study table had a unit at the left end, but since the tables were placed end-to-end against the wall, they were lighted from both sides. Each unit contained two 18-inch 15-watt fluorescent lamps, well-shielded from view. An illumination of 50 footcandles was obtained on the light-finished table tops and this, with the light-colored wall at the table front, completed a comfortable brightness pattern. Modifications of this scheme are possible for tables occupied on both sides, although less easily than for the table occupied on one side only.

7.1.2—*General Lighting*

7.1.2.1—*General* — General reading room illumination of the levels given in Table III will be most acceptable where the time of room occupancy is high enough to justify operating the system all of the time. Lighting engi-

Figure 8. General lighting for this small public library is provided by a rectangular pattern of fluorescent troffers.

Figure 10. (Top) Stack illuminated by 100-watt filament lamps in stack lighting luminaires mounted 7′ 6″ above the floor and 6′ 6″ apart.

Figure 11. (Middle) Short stack aisle used for storage and file purposes illuminated by two four-foot two-lamp semi-direct fluorescent luminaires.

Figure 12. (Bottom) This experimental stack lighting installation in the Cleveland Public Library illustrates the advantage of using reflectors punched with vertical slots to illuminate the upper shelves. The front reflector is parabolic and unslotted, center is ellipsoidal and slotted, rear is slotted parabolic. In foreground note the darkness of upper shelves resulting from reflector cut-off. All units contain four-foot 300 ma slimline fluorescent lamps and are cross-louvered with 25-degree shielding lengthwise.

neers will have two types of rooms to consider: rooms with high ceilings (16 or more feet), and those with low (9-16 feet). Most present libraries of older design have fairly high ceilings and some to be built in the future will undoubtedly be of similar construction. However, in view of increased building costs, and improved methods of ventilation, many new libraries will follow the current trend in schools and office buildings in the use of lower ceilings.

7.1.2.2—*High-Ceiling Rooms* — **(a)** High ceiling rooms that are light in color and plainly or sparsely decorated can be illuminated with indirect, semi-indirect, semi-direct, or large-area, low-brightness direct installations such as artificial skylights and indirectly lighted coffers. See Figs. 1 to 3. General diffusing systems using either light source, e.g., enclosing globes and unshielded fluorescent tubes, are not suitable for reading rooms because the large amount of light at angles near the horizontal becomes a source of direct glare in systems providing the levels of illumination required.

(b) The design of direct lighting installations for reading rooms is more critical than for most other types. Careful attention should be given to the following: minimizing high brightness ratios between luminaires and adjacent ceiling areas; the problems of the spacing distance and mounting height of luminaires; and to the use of luminaires which have an acceptably low brightness in the zone from vertical to 45° to minimize reflected glare from tables and glossy paper. Because of their lower source brightness and higher efficiency, fluorescent lamps will probably be most commonly used. Incandescent lamps are satisfactory if shielded in the 0-45° zone by glazing with a good diffusing material, or by the use of silvered-bowl lamps in diffusing coffers or cavities of high reflectance.

(c) High rooms with dark, decorated, or heavily beamed or coffered ceilings are difficult to light and still retain the original architectural features. In some libraries, the present lighting for reading rooms consists of large decorative chandeliers, which are widely spaced and generally unsuited for the production of the recommended general illumination. It may be possible to convert some of these luminaires into a direct or direct-indirect form that can produce sufficient footcandles comfortably, and still be in keeping with the room decoration. See Figs. 3 and 4. Many units will be impossible to convert and should be replaced.

(d) Some ceilings have cavities where flush, built-in luminaires can be installed. Examples of such architectural features are panels, coffers, and beams which are so spaced that they naturally form the sides or enclosure for direct, louvered, or glazed luminous elements. Such ceiling areas are also natural locations for close-ceiling and suspended luminaires. By intelligently utilizing these architectural elements, general lighting congruous with the decorative plan can usually be provided. Since no two rooms are alike, such installations are preferably planned by a lighting engineer working with an architect.

(e) Where it is not possible, or desirable, to light high-ceiling, heavily decorated rooms as discussed, commercial fluorescent luminaires of the close-ceiling or suspended types should be considered. These can be arranged in continuous or intermittent rows, and in rectangles, squares, or other geometrical patterns. Where the ceiling is generally dark and a good utilization of light at the reading level desired, direct-indirect and semi-direct fluorescent luminaires are indicated.

Enough light reaches the ceiling from units of these types to light the ceiling decorations and to relieve any tunnel-like effect caused by dark ceilings.

7.1.2.3—*Low-Ceiling Rooms*—**(a)** New libraries will require increased flexibility in the utilization of the space for reading rooms, conference areas, stacks, or any of the newer facilities offered by modern library institutions. The lighting designer must accordingly incorporate flexibility features in the lighting to a degree not heretofore necessary.

(b) The lighting of libraries with low ceilings, 9-11 feet, will have to be of a type suitable for reading room purposes without interfering with book stacks. (See Figs. 7, 8 and 9.) Suspended types of luminaires should be high enough to clear stack ranges. In such buildings, the emphasis will undoubtedly be on flush, ceiling-mounted, and short-stem suspended units. Because low-ceiling rooms will provide space above the ceiling for ventilating ducts, pipes and electrical raceways, the location of individual lighting units, or rows, must be co-ordinated with other utilities.

7.2—*Book Storage Areas*

7.2.1—*Wall Shelves*—**(a)** It is common practice to store books on wall shelves in small libraries (*e.g.,* public schools, branch libraries, etc.) and in some areas of large libraries where easy access to certain books is wanted, such as in browsing rooms, children's reading rooms, and specific reading and research departments.

(b) Where good general illumination is present, there will probably be no need for supplementary shelf illumination, especially where luminaires are located close enough to the shelf-lined walls to compensate for the lower illumination values obtained there at normal spacings. This spacing is less critical for indirect lighting than for direct or semi-direct systems. Book shelves located between, or adjacent to, windows open to the sky may need supplementary lighting because of the glare from the sky brightness, even though they may be lighted to the same footcandle value as other shelves.

(c) Supplementary shelf lighting units are often spaced too far apart along the shelves resulting in spotty illumination, or too close to the shelf faces, the upper shelves receiving most of the lighting and the bottom very little. The former condition can be corrected by closer spacing or using continuous angle trough reflectors for filament or fluorescent lamps.

Figure 13. Illustrating stack lighting by means of filament-lamp luminaires with supplementary units for carrel.

(d) The spacings of individual lighting units along the shelf should not exceed 0.80 H (where H is the mounting height of the units above the floor) unless specially designed. If a fairly uniform illumination from top to bottom shelves is wanted, the individual units, or angle troughs, should be located a distance (D) out from the shelf face not less than 0.50 H. Where this is not practical or desirable, the distance out (D) can be reduced to 0.25 H if a narrow beam lighting unit designed for such applications is used. The center of the narrow beam is usually aimed slightly below the center shelves, and the reflector cut-off or distribution must be high enough to illuminate the upper shelves.

(e) Although the average footcandle value and its distribution over the shelf face will depend upon the efficiency and light distribution characteristics of the lighting equipment, it can be estimated that an average of 10 footcandles will be obtained for each 200 lumens per running foot of shelf length supplied.

7.2.2—*Piers*—Book piers, or shelf sections, that protrude into the room add book storage capacity and are also very useful in breaking large reading rooms into smaller and more intimate alcoves. These protruding sections absorb light and thus reduce the utilization of both natural and artificial light. Because of this, supplementary shelf lighting may be needed in such alcove sections. It is possible, however, to so locate and arrange the general lighting system luminaires with respect to the alcoves and shelves that satisfactory reading illumination is obtained, and no additional light will be needed on the shelves.

7.2.3—*Stacks*—**(a)** Those who are searching for books in the book stack area are usually there for a relatively short time. During that time, however, it is necessary to read quickly a great many book titles located on any shelf between the top and bottom. The task is made more difficult by the predominance of dark bindings, their scuffed condition, and half-obliterated titles and classification numbers.

(b) Undoubtedly, the stack areas have the least satisfactory illumination in most libraries. Practically, the problem is to illuminate adequately, from top to bottom and end to end, the walls of a room with dark walls and ceiling, 2½ to 3 feet wide, 15 or more feet long, and 7 feet high. The logical

position of light sources is on the center line of the aisle at the ceiling, however, under these conditions they may be six or more feet from the bottom shelves, with the light striking the book titles at a very oblique angle. Because one must look up to read book titles on the upper shelves, the glare from the light source, which may be only two feet away, should be reduced to the point where it presents no interference with vision. (Daylighting is seldom used in stacks.)

(c) The problem of adequately lighting book stacks is further complicated in some of the new modular libraries by the need for complete flexibility in the location and arrangement of the stack ranges. This means that where the luminaire positions are fixed, the stack faces may fall into any position with relation to the luminaires. The need is for a lighting system which is suitable for any arrangement of stack ranges and adequate also for the purposes of a reading room in the event that such rearrangements are made.

(d) It has been common practice to light stack aisles by low-wattage (25-40 watts) filament lamps, with or without flat shades, spaced six or more feet apart along the aisle. However such lamps are glaring and the illumination on the stack faces is very spotty, varying from 30 footcandles at the top to 0.3 at the bottom; the illumination between lamps drops to an even lower figure. The illumination can be made more uniform by spacing lamps close together, but this increases the glare because of the additional lamps.

(e) The results of tests with many specially designed stack lighting units show that rows of luminaires using filament lamps or continuous rows of fluorescent lamps with concentrating louvered reflectors can provide good uniformity of illumination from the top to the bottom shelf. (See Figs. 10 to 13.)

(f) Lighter-colored ceilings than those now commonly used in stack areas will aid in the utilization of light from any unit; light-colored floors will increase the illumination on the bottom shelf. Tilting the books on the bottom row of some types of stacks will make it possible to obtain more footcandles on the titles and make them easier to read.

7.2.4—*Carrels* — In some libraries, carrels are placed at the ends of the stack ranges as small enclosures, each with a study shelf and chair, or they may be simply open study tables at the ends of the stacks. See Fig. 13. They occur in other libraries as small reading areas located close to the stacks, or built into the stack rows where browsing among books in the stacks may be convenient. In the case of carrels open at the top, the general illumination of the area containing them should be designed to provide the proper level and quality of illumination for reading. Closed carrels should be treated as small rooms and may be lighted in either of two ways. A system of general illumination may be used which diffuses the whole carrel with light. Localized general lighting is suitable if properly arranged to avoid high brightness ratios and veiling reflections on the printed page.

Figure 14. Bilateral daylighting in children's room, Brooklyn Public Library. Note reading racks at far left and right.

Appendix A

Reading Racks

Any report on conditions which are intended to make reading easier would be incomplete without consideration of the problem of tilting the book at right angles to the reader's normal line of vision.

Few libraries now have any provisions for supporting the book being read in any position other than flat on the table. Books laid flat are in a plane about 45 degrees from the reader's line of sight; the result is that the type is foreshortened and, therefore, has an apparent height less than normal. For example, material printed in 10-point type is seen at its true height when the book is held at right angles to the line of vision; it has an apparent height of only 7-point type when the book is laid flat on the table; type width is not changed, but its visibility, and certainly its readability, has been materially reduced because of the foreshortening of its height. Laboratory tests have shown that more illumination is required to make reading matter laid flat on the table as readable and visible as when it is held normal to the line of vision.

Many readers hold their books at the most advantageous angle, but this is not practical for long reading periods, and certainly not so for the student who must write or take notes as he reads.

Methods for holding the book in the desirable position might be simple movable book racks. Other methods might include adjustable racks built into the reading table or desk tops at each chair position. Whatever the method used, a flat area is needed at either side of the rack for writing purposes on assumption that writers may be either right- or left-handed.

Probably one good reason for reading racks not being more commonly used is the fact that they are not practical for use with reading table lamps. With the trend toward the exclusive use of general illumination, however, we may find the increased use of reading racks, especially for those who must read intensively or for long periods.

Appendix B

Daylighting*

The amount of daylight received in a room interior depends among other fac-

*For further information see I.E.S. Recommended Practice of Daylighting," ILLUMINATING ENGINEERING, February 1950.

tors upon the total area of the windows and their ability to transmit light. Of equal, or greater, importance in getting the light distributed to the side of the room having no windows is the height of the window in relation to the room width, since it is the upper portion of a window that contributes the most light to the opposite side of the room. A ratio of window height to room width of 0.5 is indicated as the lowest ratio providing minimum requirements. Greater ratios will produce not only higher illumination values at the back of the room but also improvement in the uniformity.

No doubt, this need for the greatest possible utilization of natural light was one of several factors which led to the use of high ceilings and windows in most of the libraries designed during the past. Modern techniques in obtaining good air-conditioning and artificial lighting have removed much of the need for high-ceilinged rooms and this, coupled with increased building costs, may lead to generally lower ceilings. Libraries now under construction have ceiling heights in the clear as low as 9 feet 3 inches; the usefulness of daylight in such an interior is limited practically to a band along the fenestrated side equal to about twice the window height if unilaterally daylighted, or about three times the height if lighted from two sides.

In the interest of maintaining comfortable seeing conditions in reading rooms, the type of glass used in windows, the method and degree of shading the windows, and the reflectance values of major room surfaces become important. Polished plate or clear sheet glasses or light directing glass block are employed in windows. The prismatic light-directing glass blocks are designed to redirect a part of the sunlight falling on the blocks outside to the ceiling of the room interior for reflection to the back of the room. Techniques have been developed for using these blocks in combination with clear glass vision strips and Venetian blinds of both fixed and adjustable blade types. When sheet glass or glass block having a lower transmission factor than clear glass is used, the window area must be increased to obtain corresponding illumination levels.

Window shades, baffles, or louvers should be used for the windows in reading rooms, offices, and other areas when the sky brightness or sunlight becomes uncomfortable or glaring to persons reading or working in fixed positions. Horizontal or vertical overhangs outside the windows also help eliminate glare from direct sunlight. It is a good plan to orient, as far as possible, all seated room occupants so that bright windows do not fall in their normal field of view, and also so that they do not cast shadows on their reading material or work. (See Fig. 14.)

Figure 15. Louverall ceiling, entrance lobby, Lamont Library, Harvard University.

Walls and ceilings should be finished in light colors having a flat or egg-shell finish. Desk and table tops should have a flat finish and all furniture and floors should have a light color. For recommended reflectance factors see Table II, paragraph 3.2, *Room Finishes.* Periodic cleaning should be arranged to maintain the interior surfaces with high reflectance values and windows with a high transmission factor.

Appendix C

Characteristics of the Five Types of Artificial Lighting Systems

C-1—*Indirect*—The light from indirect luminaires is directed to the ceiling and upper walls which reflect it diffusely to the work plane. Because the useful light comes from a large-area, low-brightness surface, the shadows from indirect lighting are soft and reflected glare is at a minimum. When indirect lighting is used, it is essential that the ceiling be finished in a light color using non-glossy finishes and that it be maintained in good condition.

Indirect reflectors are available in a variety of designs for standard inside-frost or silvered-bowl lamps. Silvered-bowl lamps have the advantage of furnishing a new reflecting surface every time a lamp is changed, resulting in excellent maintenance characteristics. Luminous indirect luminaires are available for fluorescent lamps. Both fluorescent lamps and filament lamps fitted with light control devices are well-suited for cove lighting although the utilization is generally low.

Cove lighting, in combination with suitable room appointments, creates a restful and luxurious atmosphere. It will, accordingly, find suitable applications in assembly rooms, and for special collections and similar applications where appearance is important. It will be suitable, also for the general illumination of areas in which are located self-lighted shelves, display cases, etc., or where displays of special interest are spot or floodlighted from supplementary sources.

C-2—*Semi-Indirect*—This system is similar in character to indirect lighting; since, however, more light comes directly from the luminaire, the utilization will be slightly higher than for indirect lighting, and the shadows and reflected glare more discernable. Because of its luminous character, the luminaire itself becomes a factor in the brightness and decorative pattern.

C-3—*General Diffuse*—Luminaires of this group direct about equal amounts of light upward and downward. This group includes opal enclosing globes (filament), and bare fluorescent lamps, all of which have strong components of light in the near horizontal angles; the direct glare that results from this horizontal light makes them generally unsuited for reading rooms, offices, etc. They are suitable for use in hallways and other service areas.

Units of this classification which have most of the light in the horizontal angles shielded out are known as direct-indirect. They are available for fluorescent lamps and have about the same fields of application as semi-direct or semi-indirect.

C-4—*Semi-direct*—The desirable characteristics of this system include, (1) the high utilization of light because of its strong downward component, and (2) enough light direct to the ceiling to relieve the darkness of the ceiling encountered with most types of direct lighting. When used to light reading rooms, fluorescent equipment is preferred over filament because of the larger luminous areas, softer shadows, and lower reflected glare. Some fluorescent luminaires of this classification are open-bottom, louvered; others are covered at the bottom with diffusing glass or plastic materials.

C-5—*Direct*—This system has the maximum utilization and the simplest maintenance. Where direct lighting equipment, or downlights, are placed on wide spacings, shadows may be objectionable, illumination non-uniform, and an undesirable brightness ratio obtained between the luminaires and the adjacent ceiling areas. Dark ceilings can be lightened, however, by providing other indirect sources and, to some degree, by the use of light-colored floors, table tops and furniture. Direct lighting becomes more acceptable for library use as the luminous areas of the luminaires become larger and lower in brightness, or where the luminaires are spaced closer, approaching a uniform ceiling. One of the types of direct lighting often employed at check-out desks and other places where light is wanted over a restricted area is the filament lamp prismatic-plate type installed flush in the ceiling. (See Fig. 2.)

Coffers are one type of direct lighting well suited for general illumination in libraries. These are essentially cavities, finished in a light color, each containing lamps and shielding media. They may be either open or closed. Coffers of various shapes and dimensions become architectural elements that have many possibilities of architectural treatment because of the varieties of brightness patterns that are possible. For example, see Fig. 1.

Two useful clear materials that have in-built or self-contained louver elements are available for covering coffer openings and luminaires. One of these is plastic; the other is glass. Where the material is diffusing, it is likely that the coffer area so covered will be of fairly high brightness. Since there will be no light from the flush coffers to light adjacent ceiling areas, the high contrast in brightnesses may be uncomfortable. Indirect illumination from other sources can be used to reduce this contrast, and the light reflected by light table tops, floors and lower sidewalls will be helpful. The collection of dirt on all flat transmitting surfaces will cause a more rapid depreciation of the light output than open-bottom coffers and, accordingly, more maintenance will be needed.

Another form of direct lighting is known as the louverall system. This system employs a wall-to-wall system of multi-cell louvers above which are located fluorescent or silvered-bowl filament lamps on spacings which make the vertical louver blades reasonably uniform in brightness. The lamps can be equipped with trough reflectors or, more simply, located in a shallow cavity which, for best efficiency, should be painted or finished in a light color. (See Fig. 15.) Maintenance of louvered systems is good because dirt falls through the louver openings and has little tendency to collect on the vertical surfaces of the louver blades. For offices and reading rooms, the louvers should be designed to shield all lamps from view within an angle of 45 degrees above the horizontal.

Luminous ceilings (sometimes called "artificial skylights") are composed of direct luminaires covered by glass or plastic diffusing panels, either in sheet or woven cloth form. Such an installation reduces the brightness of the lamps and thereby reduces the reflected glare or veiling reflections in glossy reading material.

COMPLETE EXPENSE ANALYSIS

General Information	Lighting Method #1	Lighting Method #2
Installation Data		
Type of Installation		
No. of Rows		
Luminaires per row		
Lamps per luminaire		
No. of lamps		
Watts per lamp (incl. accessories)		
Total Watts		
Maintained Footcandles		
Calculation of Complete Expense		
Capital Expense		
No. of Luminaires		
Estimated cost each installed		
Total cost luminaires		
Estimated wiring per luminaire		
Total cost wiring		
Total (luminaires plus wiring)		
Assumed years life		
Total Capital Expense per Year		
Energy Expense		
Total Watts		
Average Hours Used per Year		
Kilowatt hours per year		
Average Rate per Kilowatt hour		
Total Energy Expense per Year		
Lamp Renewal Expense		
No. of lamps		
Avg. hours used per year		
Total lamp hours per year		
Rated lamp life in hours		
Avg. lamp renewals per year		
Net price each		
Replacement expense each (labor)		
Net price plus repl. expense each		
Total Lamp Renewal Expense per Year		
Cleaning Expense		
No. of washings per year		
Man-hours each (est.)		
Man-hours for washing		
No. of dustings per year		
Man-hours each (est.)		
Man-hours for dusting		
Total man-hours		
Expense per man-hour		
Total Cleaning Expense per Year		
Repair Expense		
Repairs (Based on Experience, allocation of repair man's time, etc.)		
Est. Total Repair Expense per Year		
Recapitulation		
Total Capital Expense per Year		
Total Energy Expense per Year		
Total Lamp Renewal Expense per Year		
Total Cleaning Expense per Year		
Est. Total Repair Expense per Year		
Complete Lighting Expense for Year		
Complete Lighting Expense per Footcandle per Year		

Appendix D

Comparsion of Filament and Flourescent Light Sources

D-1—*Economics*—The initial investment in a fluorescent lighting system is usually higher than for an equivalent filament system; the lighting equipments are larger and more of them are needed. Since fluorescent lamps have a longer life lamp replacements are less frequent, but the fluorescent system will require

more time and effort for cleaning and maintenance than an equivalent incandescent system. Fluorescent luminaires are available in a wide variety of types and construction; in some, the construction is simple with easy access to the lamps; others are less simple. The lamp replacement and cleaning problems should be considered and luminaires selected which are easy to relamp and clean. Artificial skylights or louverall systems built into high ceilings should be accessible from an attic space above, or provision made for portable extension-ladder maintenance devices to be operated from the floor.

The overall cost of lighting should be calculated for each lighting system because of wide variations in both the owning and operating costs. In some buildings the present wiring system may be adequate; in others, a complete rewiring is necessary. Some institutions include amortization figures; others do not. When figuring the cost of lighting equipment, it will be found that there is a wide range both within the fluorescent field, and also for filament equipment as compared with fluorescent. Variations occur, also, in the cost of electrical energy.

Complete cost figures for lighting (see Complete Expense Analysis, page 196) will include the following:

Owning Cost — Cost of luminaires plus hanging. Cost of wiring, if necessary, which includes the required number of ceiling outlets, switching controls, and branch-circuit wiring to the sub-panel board. Added to this may be the amortization which includes interest, insurance, etc.

Annual Operating Cost — This includes the cost of electrical energy based upon the annual hours of operation. To this must be added the cost of lamps for renewals, and a figure for the cost of cleaning the equipment.

So far in this report the two illuminants have been considered as being used separately; there is no inconsistency, however, in combinations of the two. Fluorescent lamps have the advantages of high efficiency in the production of light, low production of heat, and adaptability to modern architectural design; filament lamps, on the other hand, are simple and compact and, because the light sources are relatively small, a wide range of controlled-light patterns are possible, varying from the broad distribution of the silvered-bowl lamps in indirect luminaires to spot or flood beams for downlighting.

D-2—***Color Temperature***—The color temperatures of filament lamps commonly used are within the range of 2800-3000K. Fluorescent lamps of about this same range are available; such lamps could be used in combination with filament lamps with little obvious variation in appearance. Fluorescent lamps of 3500K are widely used, and those of 4500K find extensive acceptance. The 4500K lamp has a cooler appearance than the 3500K lamp and looks white without appearing cold; the 4500K lamp, particularly, mixes well with natural daylight, and both are successfully used in combination with filament lamps. Daylight fluorescent lamps are preferred by some where artificial and natural daylight are mixed, but when used alone, the room appearance—at least under low footcandle levels—may be considered cold. At higher levels of 30 or more footcandles, the cold appearance is less obvious.

D-3—***Relation to Air Conditioning***—From the standpoint of air-conditioning, the total heat load generated by the lighting system is in direct proportion to the total electrical load (watts) in the room. For filament lamps, the load is the total lamp watts; for fluorescent, it is the total lamp watts plus the ballast watts. Because fluorescent lamps are roughly 2½ times as efficient as filament lamps, the total watts required by fluorescent lamps to produce a given footcandle value is half or less that required for filament lamps. Thus fluorescent lamps will add half or less as much to the air temperature (or load on air-conditioning system) per footcandle as will filament lamps.

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